System Technology Enhancement Program

Enables Cost-Effective COTS Upgrades for Legacy System

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Procurement and engineering practices in the defense and aerospace industries have changed dramatically since 1995 – the year when "procurement reform" became a reality. Since then, Commercial Off-The-Shelf (COTS) hardware and software and Open Systems Architecture (OSA) have become the buzzwords for increasing cost-effectiveness and speeding time to market without compromising reliability, function or performance.

The use of modular Open Systems Architectures, now a mandatory part of the COTS procurement process, has provided a rational approach that allows new line replacement unit (LRU) and system designs to reap the growth potential and future-technology insertion benefits afforded by the open systems approach. As a result, military standards (MIL-STDs) that once emphasized reliability, functionality and performance over cost efficiency and upgradability have been successfully replaced by international technical and quality standards that avoid such compromises.

Initially, these procurement programs targeted the development of new systems. But perhaps the larger concern today is that many thousands of fielded, legacy systems are still in service – and are, or will be, in need of upgrades – but predate procurement reform (see Table 1).

Legacies Left in the Lurch? Not Necessarily.

To put the issue of legacy LRU upgrades into context, it is important to realize that most military platforms are designed to have a very long operational life. The United States Air Force's B-52 Stratofortress, for example, entered service in 1962 and is not scheduled for retirement until 2040 - at 80 years old! But military missions continue to change as defense planners move from the Cold War era to address present and future realities. Obviously, the avionics systems on the B-52 will not remain operationally effective or appropriate over its projected lifecycle, nor will its sensors, missiles and offensive systems. All of these will need to incorporate advancing technologies to remain mission-effective.

Still, if new systems are enjoying the benefits of COTS/OSA procurement initiatives, shouldn't legacy LRUs be able to do the same? (See Table 2). And can COTS/OSA procurement initiatives favorably impact them, as well?

The answer is yes – but only if carefully thought out. When the time comes for re-engineering, legacy LRUs can embrace the open systems approach. That is, the outmoded, outdated and less-than-mission-worthy function and performance of an aged or aging LRU, can turn to COTS/OSA – so that existing Operations and Maintenance budgets can be applied to enhance their continued functionality and performance.

Platform	Year Entered Into Service	Minimum # Deployed	Systems Affected
TOW II – tube-launched, optically tracked, wire guided heavy anti-tank missile	1970 987 1991	80,000 118,000 40,000	Target Acquisition Systems
A-10 Warthog – tactical fighter	1972	300	Mission Computer, Stores Management System
F-16 Falcon – lightweight fighter (smaller aircraft – especially tight space/ weight constraints)	1979	3900	Radar Processor, Display Processor, Mission Computer, Stores Management System
F-15 Eagle – twin-engine, high-performance fighter	1986	1000	Radar Processor, Display Processor, Mission Computer, Stores Management System
Predator UAV – unmanned (drone) surveillance aircraft	1995	N/A	Sensor Suite Processing (radio, satellite communications, surveillance and reconnaissance systems, electro-optical and infrared cameras, synthetic aperture radar), FLIR, Mission Computers
F-18 Hornet – fighter	1995-1998 (E/F versions currently in production)	600	Navigation Systems, Radar Processor, Display Processor, Mission Computer, Stores Management System
Javelin – portable anti-tank missile system	1996	10,000s	Passive Target Acquisition, Fire Control Unit

Table 1: A multitude of legacy military platforms, from avionics through missile control systems and more, are ripe for COTS/OSA upgrades. Shown here are but a few examples of STEP candidates.

Saying so, however, is easier than doing so. The task demands a comprehensive understanding of the complexities of the problem. In other words, getting there is simple – but only after drawing a flight plan that points out the threats of turbulence along the way.

A Few of the Major Issues

The road to upgrading a legacy LRU has never been easy, neither before nor after procurement reform. The following identify just a few of the major issues that have traditionally affected the upgrade of today's rapidly aging legacy systems:

- Hardware Availability
- Cost
- Architecture & Software Compatibility
- Legacy Boxes and Form Factors

Hardware availability has always been one of the major concerns in upgrading legacy systems. The majority of components used in existing LRUs are MIL-STD-883 or QPL in ceramic packages. The supply of these parts for routine maintenance and repair, particularly for older, less-dense devices, is dwindling. The same may be said of other components such as power supply units, plasma touch panels, fluorescent displays, CRT displays, and others. What's needed is an upgrade that can adjust to hardware availability.

Table 2: The Advantages of COTS/OSA Upgrades for Legacy LRUs

- The replacement board leverages a commercial, off-the-shelf design and is based on open architecture concepts.
- Software development can be started immediately using standard off-the-shelf products; migration to the reformatted target board can accommodate the design and development cycle.
- The use of a non-proprietary processor architecture enables the use of the latest software development tools, languages and operating systems again, off-the-shelf and at low risk.
- The latest technology will provide a vital advancement in the performance and functionality potential of the re-engineered LRU. As it is likely that some re-architecture of the software will be necessary to migrate to new languages and tools, the opportunity can be taken to pave the way for flexibility in the implementation of the operating system and application tasks.
- Spare capacity can be used for new applications to respond to later changes in the mission profile or anticipated threats to the platform.
- Future potential technology insertion is ensured, as the reformatted target board is a derivation of a standard off-the-shelf product.

Strongly related to hardware availability issues are the costs involved with maintenance and repair. Typically, these costs increase with time – until they reach the point where it becomes more economically feasible to replace the LRU with a design that provides up-to-date technology. This is an expensive exercise, but it does result in reduced system replacement costs – until the cost curve inevitably steepens because of parts obsolescence. That is, the LRU can be maintained and repaired, and its original functionality and performance kept intact, for as long as budgets allow. But does it make good sense to simply keep pace with technological needs without other gains? The B-52 fleet, as an example, has an identifiable and continuous need for changing its mission profiles and reactions to external threat scenarios. So, for the B-52 and many other legacy systems, the answer is that it does not make sense to merely sustain the system. What's needed is an approach that allows the continuing addressing of new mission initiatives.

Another consideration in legacy systems is the processor type and associated software development tools that were used in the initial implementation. For many systems the MIL-STD-1750A processor was mandated as the military standard processor architecture and was incorporated into many subsystems. Unfortunately, the same market forces that have reduced the number of mainstream commercial processor types to just the Pentium, PowerPC and MIPS, also spelled the end of 1750 development; military demand was just not enough to sustain a unique processor architecture.

The same is true of software development tools and the skills required to program in military-unique languages. JOVIAL has passed away, as has PASCAL, but many applications were written in these languages and are still fielded in the front-line today. Even though the source code for these programs is owned by the U.S. government, neither the skills nor the tools still exist to maintain and update these applications.

The introduction of new mainstream processor types must consider the porting of the original application (such as 1750 object code, JOVIAL or Ada source code) and the provision of new functionality to the legacy system. Tools are available to port and profile 1750 object code to PowerPC – for example, the RePLACE toolset from TRW – or to recompile the source code into an intermediate code, such as C or C++, for execution by PowerPC. Both of these methods usually introduce a new real-time operating system, such as VxWorks, which provides an API through which new application tasks can be added without disturbing the original legacy functionality.

Many legacy LRUs designed before procurement reform are characterized by either proprietary bus architectures, or perhaps no bus architecture at all. So, until the early 1990s there was little consideration given to the adoption of any kind of industry-standard OSAs such as Multibus, Multibus II, VMEbus, PIbus or Futurebus+. Moreover, many systems employed data bus and micro-coded processor instruction-set architectures that were proprietary to the original equipment manufacturer.

Form factors introduce yet another obstacle. During the design of land-based (vetronics) and airborne (avionics) platforms, little consideration was given to the accommodation of standard-sized equipment boxes or LRUs. Often, the boxes were designed to fit within an existing space envelope, and were provided with power and cooling that could vary from position to position within the vehicle. This is one of many reasons why it is often impractical to consider changing an LRU's physical profile, its power, or its cooling requirements when re-engineering a legacy system. Otherwise, the basic vehicle design could be affected which would necessitate airframe recertification – not a viable option when just one or two legacy LRUs are to be re-engineered to address maintainability issues.

In the Long Run, Stop-Gap Options Are Worthless

The most common obsolescence problem is caused by electronic components. There are a number of stop-gap options available to manage component sourcing problems, but they are not without their shortcomings. For example:

- The manufacture of parts by trailing-edge suppliers using outdated processes.
- Last-time purchases and subsequent management of large inventories.
- The repackaging of commercial die and re-screening.
- Parts substitution with an equivalent or over-specified part, often of commercial origin.
- The re-creation of the part using an application-specific integrated circuit (ASIC).
- The redesign of part or all of the LRU while retaining total form, fit, function and interface compatibility.

Unfortunately, three things are likely to interfere with these stop-gap options. For one, the rule of supply-and-demand will eventually prevail. That is, trailing-edge suppliers may cease production or raise prices as demand fades away. For similar reasons, the existing supply of commercially equivalent parts to be repackaged will disappear over time. Finally, ASIC manufacturing processes will surely change. As a result, designs will have to be shopped around for manufacture, and process changes will eventually require a redesign.

The answer in addressing all of these issues, and others related to them, then is to endorse an upgrade system that allows an aging LRU to not only meet today's standards, but can also evolve in hardware and software technologies that encourage true system-level life-cycle management.

Three Keys to Effective Upgrades and Lifecycle Management

Any successful overall strategy designed to preserve a system's or LRU's integrity, performance and maintainability over an extended period of time should consist of three elements: Open Systems Architecture, Functional Partitioning and Technology Insertion.

Open Systems Architecture. This may refer to a backplane bus or serial network architecture. Its selection provides vendor and technology independence – plus a long-life backbone architecture that continues to evolve while maintaining backward compatibility.

Functional Partitioning. Generally, what is being replaced in legacy LRUs is the processor core, memory, timers, and so on. The remainder of such a system is usually less vulnerable to obsolescence as it tends to use devices that are unique to the military environment and have long-term support from niche semiconductor manufacturers.

Technology Insertion. This is the capability to insert improved technology, perhaps in batches, throughout the remaining production and support life of the program. Technology insertion is essential and should always be considered when replacing a legacy module because it allows the system’s life to be extended beyond the current upgrade. Designers of software and systems need to recognize the specifics of the application's hardware and make them transparent to future technology refreshes.

Technology insertion is the model that many of today's integrators are adopting in both new and existing system designs to protect against future obsolescence. Fortunately, using these concepts, this model can be made equally applicable to legacy upgrades. Technology insertion will be supported by many Open Systems suppliers in the evolution of their standard product lines. The technology insertion model requires serious commitment to continuously update and replace vulnerable product lines and their form-factor derivatives by maintaining form, fit and function compatibility and a consistent backward-compatible application programming interface (API) to drivers and operating system calls.

A Systematic Approach

DY 4's approach to solving the legacy LRU upgrade conundrum is a methodology called the System Technology Enhancement Program (STEP). This methodology is designed to leverage the best of today's COTS product technology, and reformat it to fit within the parameters of existing legacy LRUs that cannot otherwise accept off-the-shelf products (Figure 1).

Such leverage is achieved by modularizing the design of new COTS products, such as single board computers (SBCs) or DSPs. Today's SBCs and DSPs, for example, are targeted primarily for VMEbus and IEEE 1101.2 mechanical standards and, more recently, for CompactPCI in a 3U form factor. But if they are treated as basic building blocks for re-use, a COTS vendor can produce functionally equivalent circuit card assemblies on a legacy form factor – and even to a legacy data bus architecture for technology enhancement. In this way, a form-factor-equivalent processor board using the most current technology can replace a proprietary processor board.

Using standard product design modules, STEP allows the replacement board – based on open architecture concepts such as VMEbus or CompactPCI – to leverage a COTS single-board computer or digital signal processor design. As a result, vendors can better deliver COTS hardware and software to fit existing legacy LRUs, thereby extending their useful life, upgrading their performance and increasing their flexibility.

DY 4's STEP program enables today's existing legacy to break the continuous and costly cycle of technology reengineering. It encourages the introduction of COTS-derived technology into legacy systems to extend their useful life, to upgrade performance and to make legacy LRUs more flexible and ready to accept the inevitable next step in performance when it is required.

The STEP methodology provides a means to an end, which is the reduction of obsolescence and the insertion of a COTS architecture.

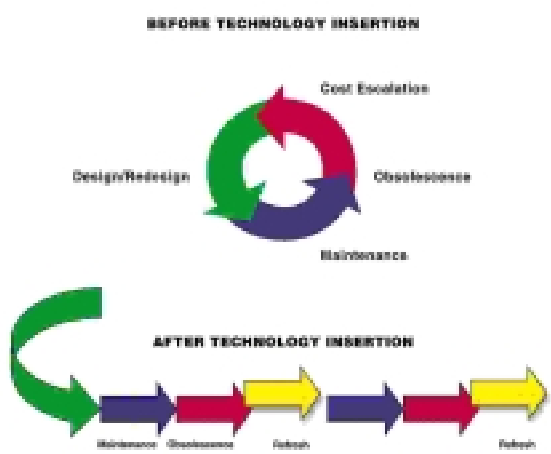

Figure 1: Historically, proprietary military platforms followed a costly cycle of design, maintenance, obsolescence, cost escalation and redesign, perhaps rendering a platform obsolete well before its intended life cycle expired. Today, strategies such as DY 4's STEP program can update with COTS these same legacy systems. The systems can then be continually maintained and upgraded for the intended life of the platform